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AN IMPLEMENTATION STUDY OF AN ACCOUNTING SYSTEM DESIGN FOR THE NAVAL AVIONICS CENTER

by

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This thesis conducts a comparative analysis of NIF cost accounting with activity-based cost (ABC) accounting in order to determine which cost accounting system more accurately accounts for the resources of the RAMP PWA facility, and which system reports a more precise estimate of product costs.

The author concludes that an ABC system can more accurately account for the resources of an automated manufacturing facility, and that an ABC system reports a more precise estimate of product costs.

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An Implementation Study of an Accounting System Design for the Naval Avionics Center

by

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ABSTRACT

The Navy is constructing an automated manufacturing facility which incorporates a flexible manufacturing system (FMS) and computer-integrated manufacturing (CIM) technology. The facility, which is known as the RAMP PWA facility, will operate within the Navy Industrial Fund (NIF) system.

This thesis conducts a comparative analysis of NIF cost accounting with activity-based cost (ABC) accounting in order to determine which system more accurately accounts for the resources of the RAMP PWA facility. Additionally, the thesis seeks to determine which costing system reports a more precise estimate of product costs.

The author concludes that an ABC system can more accurately account for the resources of an automated manufacturing facility, and that an ABC system reports a more precise estimate of product costs.

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I. INTRODUCTION

A. BACKGROUND

Construction is underway on an automated manufacturing facility which incorporates both flexible manufacturing system (FMS) and computer-integrated manufacturing (CIM) technologies. This facility, which is known as the Navy's Rapid Acquisition of Manufactured Parts Printed Wiring Assemblies (RAMP PWA) program, will be established at the Naval Avionics Center (NAC) in Indianapolis, Indiana. (RTIF Program Document-B, 1989)

The Navy's requirements that led to the concept for the development of a RAMP PWA Manufacturing System resulted from the realization that maintaining the fleet at a high state of readiness required repair and replacement parts be available in a timely manner. However, frequently when parts were ordered, delivery took too long – sometimes over a year – or worse, parts could not be obtained at all. In some cases, systems in other ships or aircraft had to be cannibalized to provide a necessary repair part. To overcome this situation, a large inventory of repair/replacement parts has been established to maintain fleet readiness at an acceptable level. (RTIF Program Document-B, 1989)

Consequently, the Navy determined that if quality printed wiring assemblies (PWAs) could be manufactured in a short enough period of time to meet fleet operational needs, they would be able to reduce the quantity of parts kept in inventory. They could also avoid having to cannibalize other operational units and realize an increase in readiness, as well as a cost savings in Navy Stock Fund expenditures. (FAI, 1986; RTIF Program Document-B, 1989)

Thus, the Navy, in the early 1980's, forged ahead with the development of the RAMP Manufacturing program. The RAMP program is split into two projects: Small Mechanical Parts and Printed Wiring Assemblies (PWA). (Bryant, 1988) This thesis addresses only the PWA project.

The RAMP PWA center will be integrated into the NAC, which is a Navy Industrial Fund (NIF) activity. (NAVCOMPT-B, 1985) Since the center will be an activity within NAC, RAMP PWA will also be included in the NIF system.

Historically, NIF activities operate under a labor-intensive manufacturing process. As a result, the NIF cost accounting system supports a labor-intensive process which allocates indirect costs on a direct labor hour basis. (NAVCOMPT-B, 1985) However, as stated above, the RAMP PWA project will incorporate state-of-the-art FMS and CIM technologies in its manufacturing process. (Bryant, 1988) Use of these technologies have significantly altered the traditional manufacturing environment from one which was primarily labor-intensive to one that is overwhelmingly machine-intensive. This movement, toward manufacturing automation, has shifted the composition of the percentage of production costs from labor costs to direct materials and overhead. Today, some estimates have placed labor costs at only five percent of total production costs. (Raffish, 1991) Yet, NIF activities continue to allocate these rising overhead and indirect costs by a diminishing labor base. (NAVCOMPT-A, Undated)

Bryant (1988) and Murphy (1988) investigated the adequacy of the NIF accounting system for use within RAMP and determined that some changes were needed in order to more accurately account for resources within a highly automated manufacturing environment. In addition, current accounting research also implies that traditional, volume-based cost-accounting systems introduce cost distortions when used in automated manufacturing processes. (Cooper and Kaplan, 1988a;

Cooper, 1989; Kaplan, 1988) Therefore, an alternative to traditional costing systems should be explored.

B. THESIS OBJECTIVE

The purpose of this thesis is to conduct a comparative analysis of a traditional cost accounting system with an activity-based cost accounting system, and determine which costing system is better able to account for resources in the RAMP PWA center. The determining factor for which system to use shall be based on the accuracy of each system's reported product cost.

1. Scope, Limitations, and Assumptions

The scope of this thesis is limited to an accounting perspective; therefore, some aspects of the RAMP PWA Manufacturing System are not addressed. Additionally, it is recommended that studies completed by Bryant (1988) and Murphy (1988) be read prior to reading this thesis. Bryant and Murphy provide an in-depth analysis of both the NIF cost accounting system and internal accounting procedures which will aid in the understanding of the problems and recommended solutions presented here. Further, the detailed description of the RAMP Program, previously presented by Bryant (1988), is not repeated in this thesis; it is assumed the reader has an adequate level of knowledge regarding the RAMP Program.

Only internal RAMP PWA accounting issues are addressed in this thesis. Issues pertaining to allocations of NAC general and administrative and other production overhead to the RAMP facility are not considered and could be the basis for further research.

C. RESEARCH METHODOLOGY

Three research methodologies (Archival, Empirical, and Analytical) were used to develop and analyze the information presented in this thesis.

1. Archival Research

Archival Research, in the form of a detailed literature review, was used to explore three major subject areas: the RAMP PWA Manufacturing System, traditional cost accounting, and activity-based cost accounting. The sources of archival information for each subject are detailed below.

Information on the RAMP PWA Manufacturing System was drawn from an extensive review of technical publications produced for the Government by research and development consortiums (American Manufacturing Research Consortium and the South Carolina Research Authority).

Information regarding traditional cost accounting inadequacies was drawn from the Navy Comptroller Manual, NAVSO P-1000, Volume 5, the NAVSEA Navy Industrial Fund Financial Management Systems and Procedures Manual, NAVCOMPT Introduction to the Navy Industrial Fund, Bryant (1988) and Murphy (1988) theses, and an extensive review of books and periodicals.

Information regarding activity-based cost accounting was also drawn from an extensive review of books and periodicals.

2. Empirical Research

Empirical Research was conducted in the form of field interviews. Personnel at the RAMP project office and the South Carolina Research Authority were interviewed to clarify issues related to the RAMP project and the RAMP PWA facility. Personnel at the Naval Avionics Center were interviewed to clarify NIF accounting procedures and to glean areas of concern regarding the RAMP PWA implementation accounting issues.

3. Analytical Research

Analytical Research was used to analyze data, develop a hypothetical RAMP PWA cost accounting analysis model, and to develop conclusions regarding which cost accounting system is better able to accurately account for resources within the RAMP PWA center.

D. THESIS ORGANIZATION

This thesis has five chapters. Chapter I is the introduction. This chapter states the objective of the thesis, provides the reason why this thesis was necessary, and discusses the research methodologies employed. In Chapter II, an overview of the purpose of the RAMP PWA center and the RAMP PWA Manufacturing System is presented in order for the reader to gain an appreciation of the highly automated nature of RAMP. Chapter III is an analysis of the inadequacies of traditional cost accounting systems and also introduced activity-based cost accounting. Chapter IV develops a hypothetical product pricing model which is used to compare a traditional costing system with an activity-based costing system. Chapter V, the concluding chapter, summarizes the research, draws a conclusion, and makes a recommendation.

II. RAMP PWA: AN ADVANCED MANUFACTURING PROCESS

A. INTRODUCTION

This chapter has two purposes. One is to discuss the purpose and goals of the RAMP PWA center. The second purpose is to describe RAMP automation technology.

Two points that should be kept in mind while reading this chapter are: 1) Even though a printed wiring assembly (PWA) could be thought of generically, there are literally thousands of designs which require differing manufacturing/assembly processes and varying quantities of raw materials. 2) The goal of RAMP is to produce PWAs on demand in varying lot sizes. Consequences of these two points are product diversity and production volume diversity. (RTIF Program Document-A, 1988; Cooper and Kaplan, 1988a)

B. RAMP PWA PURPOSE AND GOALS

This section provides a summary of the purpose and goals envisioned for the RAMP PWA center. It also describes two technological developments which will enable RAMP to rapidly respond to Navy Supply System requisitions.

1. Purpose and Goals

The purpose of the RAMP PWA center is to quickly produce PWAs according to Navy quality requirements. Moreover, these PWAs are to be used as fleet replacement parts or spare parts and will be produced on an as needed basis. (RTIF Program Document-A, 1988). Specifically,

> The primary mission of the RAMP PWA Manufacturing System is to produce and deliver a variety of PWAs in an average of 27 days after receiving the order. Execution of this mission will use the just-in-time concept to establish a system to gather small quantities of a large variety of preselected components using Part Data Definition (PDD) (computer-aided design) developed in a Product Data Exchange Specification (PDES) format (computer-aided engineering), and computer controlled or assisted equipment integrated into a computer controlled system. (RTIF Program Document-B, 1989, p. 5)

RAMP PWA is a highly automated, flexible manufacturing system designed to produce PWAs with a minimum of human intervention. In order to accomplish this mission, RAMP will use the concepts of modularity, transportability, and reduction of administrative lead times in conjunction with a Computer-Aided Process Planning (CAPP) system that will be capable of producing 750 new process plans per year. Annual production capability is planned at 15,000 PWAs; production will occur in one, eight-hour work shift per day with maintenance being performed on second or third shifts. (RTIF Program Document-B, 1989)

RAMP PWA Manufacturing System Performance Goals are summarized in Table 2.1.

2. Part Data Definition and Product Data Exchange Specification Technology

Two technological developments crucial to the success of the RAMP PWA concept are the continued development and refinement of PDD and PDES. According to Kirksharian:

> PDD documents the procedures that manufacturing engineers use to gather information from paper drawings to support manufacturing documentation and planning, and final development of the PDES file technology which is being modeled to denote all data elements that completely define a product (printed wiring assembly) for all applications over its expected life. (Kirksharian, 1990, p. 100)

TABLE 2.1: PWA MANUFACTURING SYSTEM PERFORMANCE GOALS

Manufacturing Capacity	15,000 PWAs/year
Orders	1,500 Orders/year
Process Planning Capacity	750 Plans/year
Repeat Order Frequency	50% Assumed
Manufacturing Throughput Time Goals	
Administrative Lead Time	20 Days Average
Manufacturing Lead Time	7 Days Average (with 3 days for test and burn-in)
Normal Work Shift	8 Hours/day
Number of Shifts	1 Shift/day (additional shift for surge)

(RTIF Program Document-D, 1989)

In other words, PDD and PDES technologies are computer digitized design and manufacturing specifications which provide complete information on the PWA required bill-of-materials, test specifications, acceptance specifications, specific electrical performance requirements and drawings (including assembly, specification control drawings and detailed fabrication drawings) (RTIF Program Document-D, 1989). Use of the PDD and PDES technology permits the RAMP Manufacturing System immediate access to the information necessary to manufacture and test a PWA. Therefore, excessively long lead times normally associated with procurement of out-of-stock repair parts and replacement parts can be dramatically reduced, if not eliminated. (RTIF Program Document-D, 1989) This reduction in procurement lead time is a function of the highly automated nature of RAMP's Manufacturing System.

C. RAMP PWA MANUFACTURING SYSTEM

This section describes the mechanics and capabilities of the two main elements of RAMP's computer-integrated manufacturing system. The first is the Automated RAMP Logistics Support System which provides the shell or communications capability that permits interfaces within the RAMP Manufacturing System and site-external systems such as NAC's automated data processing (ADP) center. The second is the RAMP Manufacturing System which provides the capability to coordinate all aspects of the PWA manufacturing process. (RTIF Program Document-B, 1989) Following this description, a systems overview and a summary of RAMP - NAC internal and external interface requirements are presented. Finally, the RAMP manufacturing process is discussed.

1. Automated RAMP Logistics Support System

The Automated RAMP Logistics Support System (ARLSS) provides the logistics support and communications capabilities among the RAMP Manufacturing System, the RAMP Site, and site-external entities necessary to fulfill the implementation objectives of the Navy's RAMP strategic plan (RTIF Program Document-C, 1991). The functional subsystems of ARLSS include:

- Cost Accounting and Performance Measurement.
- Candidate Part Selection.
- Material Acquisition and Inventory.
- Technical Data Package.
- Staff Planning Tool.
- Customer Order Placement.
- RAMP/PDES Generation Systems Interface.
- Electronic Bid.
- Electronic Data Communications. (RTIF Program Document-C, 1991)

This thesis addresses accounting issues. Consequently, a description of only one functional subsystem of ARLSS is addressed, the RAMP Cost Accounting and Performance Measurement (RCPMS) subsystem.

a. RAMP Cost and Performance Measurement Subsystem

The RCPMS subsystem is an automated cost accounting and performance measurement system which is being developed to collect, aggregate, and report accurate, relevant, and timely data on RAMP operations. RCPMS will be

utilized by shop floor and site management personnel for product cost estimating and tracking, operational planning and control, and strategic decision making (RTIF Program Document-E, Undated). The primary purpose of the RCPMS is to be the mechanism by which unit manufacturing costs are determined and serve as a source for collecting and reporting of system-wide performance (RTIF Program Document-F, 1990).

RCPMS will be the focal point of data interchange between functional activities within the RAMP Manufacturing System, other ARLSS subsystems, and the host site (NAC) accounting/administrative functions. The cost performance subsystem will collect operational and utilization parameters from RAMP and join them with cost/pricing parameters from the site or other ARLSS subsystems. RCPMS will also generate cost/performance reports to support shop floor planning and control and accommodate site management's need for strategic decision making information. (RTIF Program Document-E, Undated)

The RAMP PWA center will be treated as a separate and independent business unit at the NAC, where multiple, diverse cost centers operate concurrently. Within RAMP, it is envisioned that multiple cost centers will be set up for all manufacturing and support functions (Interview-A, 1991). And RCPMS, in conjunction with other subsystems of ARLSS, is capable of capturing RAMP Manufacturing System data such as machine times, operator times, throughput times, other utilization measures (e.g., number of process plans generated, components inserted), and materials quantities. (RTIF Program Document-E, Undated)

The overriding goal of RCPMS is to trace activities and corresponding costs to the particular end unit which utilizes the resources. Costs which cannot be traced directly to an end unit will either be accumulated in a cost pool associated with the specific RAMP cost center that generates the resource requirement

or into a general overhead pool. Capability to allocate costs to end products by an appropriate utilization measure (e.g., number of boards processed, workstation processing times, number of components inserted) is key to RCPMS. (RTIF Program Document-E, Undated) A listing of the capabilities of RCPMS are found below. A detailed description of the mechanics and methodology of RCPMS's capabilities may be found in Appendix A.

- Bid Quotation Processing:

  Enter and maintain bid data.

  Process cost estimation.

  Cost estimate completion and closeout.

- Enter Order Data

- Enter Order Specific Item/Fixture Requisition Data:

  Enter order specific item requisition data.

  Enter order specific fixture requisition data.

- Collect and Distribute Traceable Labor Costs:

  Obtain labor rate and labor burden factors.

  Build list of pay rate differentials.

  Collect times on employee activities.

  Calculate labor costs and distribute to job.

- Collect and Distribute Non-Traceable Costs:

  Maintain cost pool look-ups and distribution table.

  Collect non-traceable labor costs.

Enter costs to capital or expense pool.

- Allocate Non-Traceable Activity Costs to Jobs:

  Maintain activity cost driver data.

  Allocate non-traceable costs to job.

  Update accumulated depreciation portion of pool.

- Job Closeout:

  Determine status of excess material/service cost.

  Perform job closeout and prepare final job cost report.

- Cost Report Generation and Archive:

  Maintain chart of periodic reports.

  Generate Reports.

  Archive closed job cost records.

(RTIF Program Document-E, Undated)

2. RAMP Manufacturing System

The RAMP Manufacturing System provides the capability "to plan, generate manufacturing data, initiate, monitor, audit, communicate, control, and perform all activities required in the manufacturing of PWAs." (RTIF Program Document-B, 1989, pp. 5-6) This capability is accomplished through the following five functional components:

- Production and Inventory Control.

- Manufacturing.

- Manufacturing Engineering.
- Quality.
- Information Management and Communications. (RTIF Program Document-B, 1989)

Table 2.2 provides a more detailed description of the five functional components of the RAMP Manufacturing System.

TABLE 2.2: RAMP MANUFACTURING SYSTEM COMPONENTS

Production and Inventory Control

Production and Inventory Control acts as the primary channel for printed wiring assembly order information and order status information from and to the Navy Ordering Activity. The PDES data is received in Production and Inventory Control which extracts and forwards electronic job data to Manufacturing Engineering.

Manufacturing

Upon receipt of a process plan, Manufacturing obtains and sends instructions to the production equipment. Activity and status data are received back from the production equipment as assembly operations progress and are used to trigger information flow to and between other RAMP PWA functional components.

Manufacturing Engineering

Manufacturing Engineering establishes process planning, production equipment instructions, operator instructions, and inspection/testing instruction.

Quality

Quality is responsible for resolving quality of manufactured parts problems. Quality requests that Manufacturing Engineering evaluate problems and receives back the cause of the problem and a corrective action plan. Problem disposition given by cognizant technical authority is supplied to Quality when needed.

Information Management and Communications

The Information Management and Communications functional component links and supports the functional components described previously (ARLSS and RCPMS subsystem) by providing basic communications, data transfer, and database services. The RAMP Order Manager, which is part of this functional component, manages the group of functional components by sending information to and receiving status from each one.

(RTIF Program Document-B, 1989)

3. Systems Overview

The RAMP flexible manufacturing system is based on a hierarchical level of control. The systems control hierarchy is designed to process information from the lowest common element of equipment status and control through the interface (i.e., largely administrative) requirements of the PWA center. Specifically, this hierarchy involves equipment, workstation, cell, system, and industrial site (NAC) functions. (Kirksharian, 1990)

The RAMP PWA systems architecture is both modular and hierarchical in nature. The RAMP hierarchy governs and processes information from the five manufacturing systems functional components previously discussed; however, only four functional components serve as primary cell controllers. They are: Production and Inventory Control (P&IC), Manufacturing Engineering (ME), Manufacturing Control (MC), and Quality control (QC) (RTIF Program Document-B, 1989).

The Ramp Order Manager (ROM) is a systems controller which provides centralized management for all software functions within the RAMP Manufacturing System and also coordinates the NAC ADP systems interface. (Kirksharian, 1990) Figure 2.1 depicts the system architecture and scope of the RAMP PWA manufacturing cell. (RTIF Program Document-C, 1991)

Functional software requirements of the four primary cell controllers and their workstations are met by available off-the-shelf software. The system design and integration of these off-the-shelf products is one of the primary goals of the program. The ROM, through a communication system (ARLSS or subsystems of ARLSS), allows the system to initiate, process, and monitor a number of both manufacturing and administrative procedures. These include order processing, material control, tool and fixture development, shop work order scheduling, and process quality monitoring. (Kirksharian, 1990; RTIF Program Document-B, 1989)

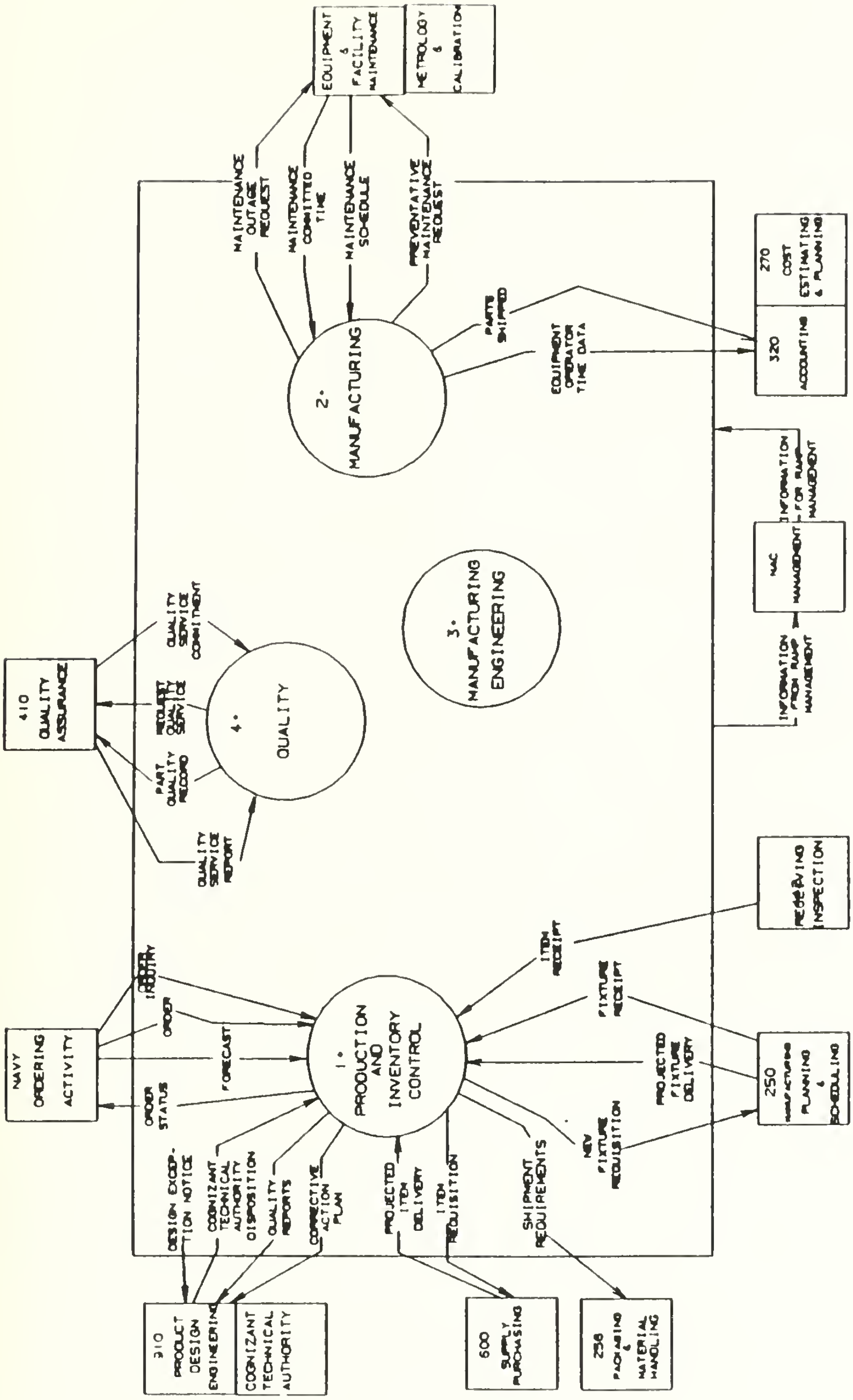

Figure 2.1: RAMP PWA Manufacturing Cell

The manufacturing system utilizes a relational data base management scheme which permits the ROM to access a common data base for storage and retrieval of required information. Work cell controllers maintain their own local data base to access application specific information associated with P&IC, ME, MC, and QC. The network updates the shared common data base as information is processed. The fifth manufacturing system's functional component, Information Management and Communication provides for the storage of all data shared by the various system components and is governed by a data base management system (ORACLE), which provides for the transfer of shared data between the common data base and the off-the-shelf application packages. (Kirksharian, 1990; RTIF Program Document-F, 1990)

Each manufacturing cell controller delegates all equipment control functions to the 13 workstation controllers. Each workstation controller operates in a multitasking environment and is PC (i.e., personal computer) based. Individual workstation PCs accept instructions and plans sent to it from the manufacturing cell controller. Workstation control allows the routing of graphical and textual instruction to the individual operator and transfers command files to equipment controllers and programmable logic devices (e.g., automatic storage and retrieval system, robotics, machinery). The workstation controller gathers data and status on the various manufacturing processes that it monitors and controls. These items are reported back to the manufacturing cell controller as required (Kirksharian, 1990). Table 2.3 lists the 13 workstations which comprise the RAMP PWA manufacturing cell; a detailed description of workstation activities are found in Appendix B.

TABLE 2.3: RAMP PWA MANUFACTURING CELL WORKSTATIONS

- Receiving Workstation.
- Storage and Retrieval Workstation.
- Board Preparation Workstation.
- Pre-Solder Assembly Workstation.
- Pre-Solder Inspection Workstation.
- Solder Workstation.
- Post-Solder Assembly Workstation.
- Post-Solder Inspection and Repair Workstation.
- Mechanical Assembly Workstation.
- Test Workstation.
- Conformal Coating Workstation.
- Final Quality Control Workstation.

(RTIF Program Document-D, 1989)

4. RAMP PWA Systems Interface

The RAMP PWA center must interface not only with internal systems but also with external systems. There are nine NAC activity functions linked to the RAMP PWA center by data transfer. The nine activities are Equipment and Facility Maintenance, Cost Estimating and Planning, Accounting, Receiving Inspection, Manufacturing Planning and Scheduling, Packaging and Material Handling, Supply/Purchasing, Product Design Engineering, and Quality Assurance. The RAMP PWA center is also linked to three other types of external organizations: Navy ordering activities, cognizant technical authorities, and metrology and calibration. (RTIF Program Document-A, 1988) Figure 2.2 summarizes RAMP PWA - NAC internal and external interfaces. (RTIF Program Document-A, 1988)

5. The Manufacturing Process

The RAMP PWA Manufacturing System is designed to physically assemble and electrically test PWAs and to verify compliance with design specifications and military requirements. RAMP's manufacturing process is designed for minimal human intervention with automation technology providing every aspect of control, planning, and execution of the design and assembly of PWAs.

Upon the generation of a supply system requirement for a RAMP candidate part, a PDES file is electronically transmitted to the RAMP PWA center where, after acceptance, a "shop order" is authorized and the manufacturing process begins. Actual assembly/manufacture of PWAs will occur by sequencing through some or all of the 13 workstations which comprise the RAMP PWA manufacturing cell. Production scheduling and individual assembly requirements will dictate the order in which each PWA will navigate its way through the assembly process - dependent upon the availability of materials, machines, required delivery date, and manpower. The PWA center operates automated production, test, and material

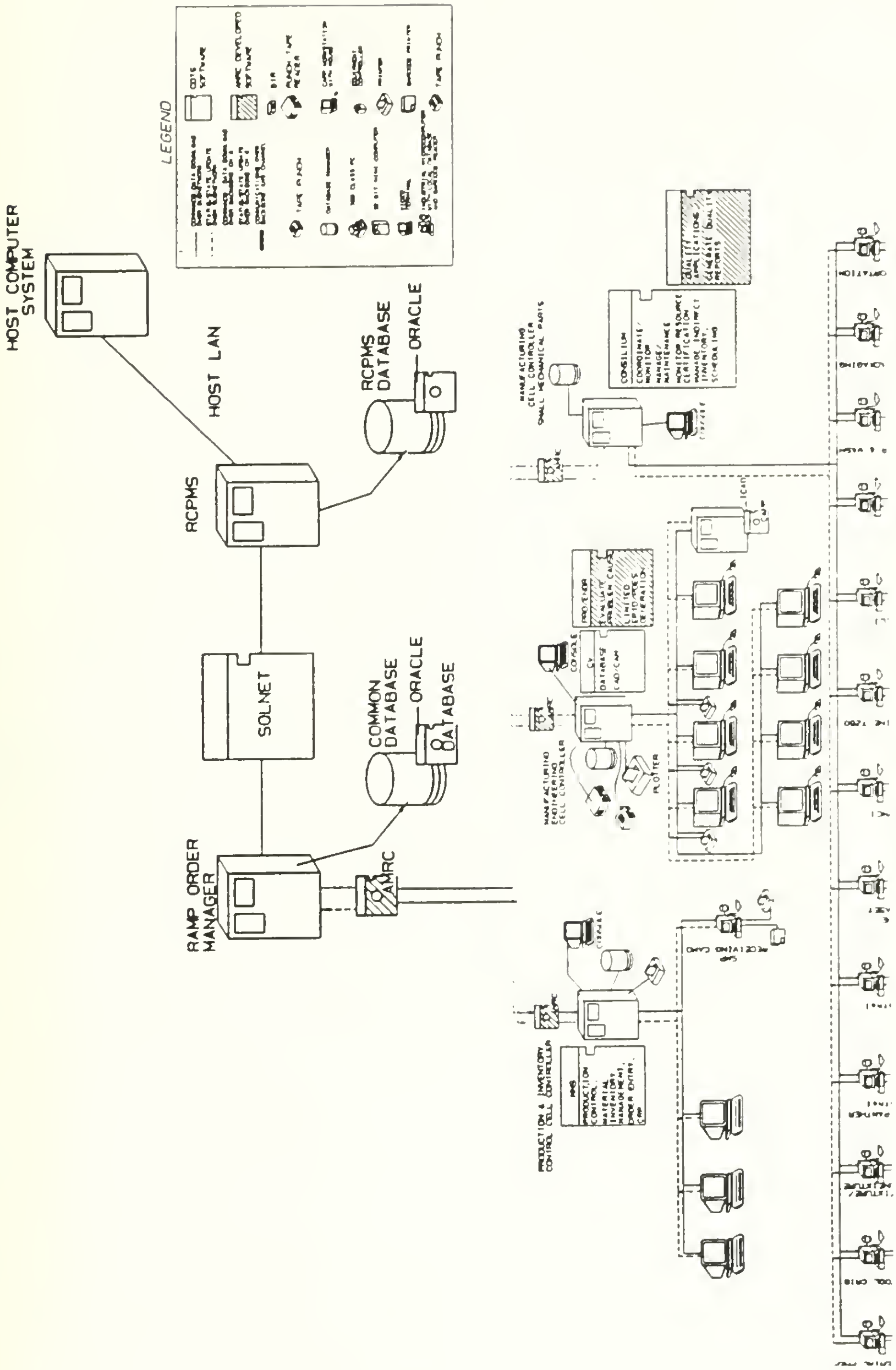

Figure 2.2: RAMP PWA - NAC Interfaces

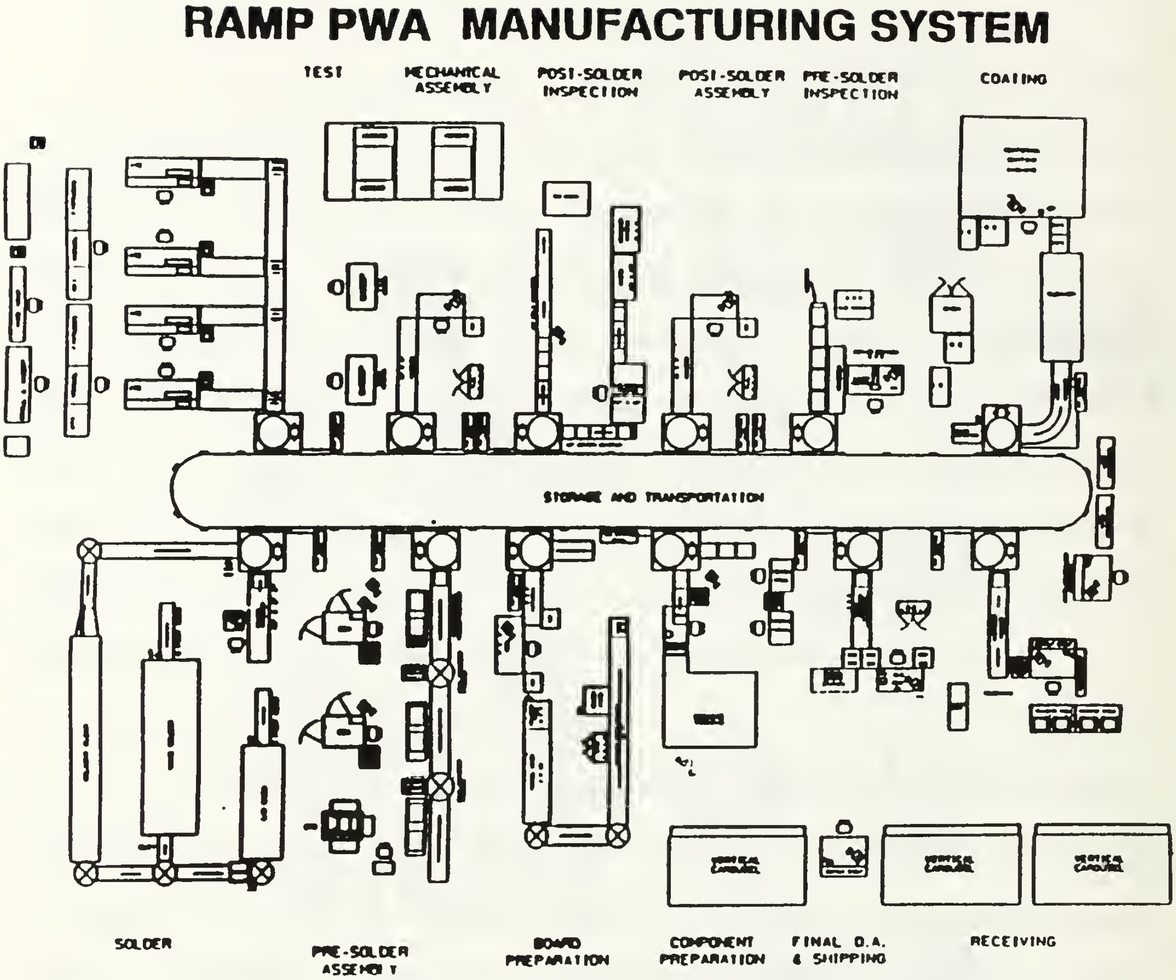

Figure 2.3: Floor Plan for the RAMP PWA Manufacturing Cell

handling equipment to produce PWAs according to customer specifications. The RAMP Manufacturing System prepares processing instructions for the manufacture of each assembly and controls and coordinates the movement of boards, components and processing instructions to and from the equipment. (RTIF Program Document-B, 1989; RTIF Program Document-D, 1989; SRI International, 1986) Figure 2.3 depicts the floor plan for the RAMP PWA manufacturing cell. (RTIF Program Document-B, 1989)

D. SUMMARY

The RAMP PWA Manufacturing System is a flexible manufacturing system which incorporates computer-aided design, computer-aided engineering, computer-aided-manufacturing, and computer-integrated manufacturing technologies. This flexible system is driven by delivery requirements and produces printed wiring assemblies only when needed as fleet replacement parts or spare parts. When production is required (i.e., an order is received), the wiring assemblies are expected to be produced in varying lot sizes. Consequently, the RAMP PWA manufacturing process is subject to both product diversity and production volume diversity, which may entail cost accounting implications.

The next chapter describes typical problems associated with traditional cost accounting systems when they are used to account for resources in an automated manufacturing environment. Also, activity-based costing is introduced and described as a possible alternative to traditional costing systems.

III. ACTIVITY-BASED COSTING: AN ALTERNATIVE?

A. INTRODUCTION

The chapter has two purposes. One is to explain how traditional, volume-based costing systems can misrepresent product costs, particularly when dealing with product and volume diversity. The second purpose is to explain how activity-based costing systems, if properly designed, can provide management with more accurate cost information. (Euske, In press)

B. NIF COST ACCOUNTING IMPLICATIONS

This section presents an overview of the NIF cost accounting system and highlights potential problem areas which may be encountered if this volume-based costing system is used to account for resources within the RAMP PWA center.

1. Navy Industrial Fund Cost Accounting

The purpose of the NIF cost accounting system is to provide meaningful information that facilitates intelligent and efficient administration of an activity. (NAVCOMPT-A, Undated)

NIF uses a standard double entry, accrual basis cost accounting system. Expenses and revenues are recognized in the period in which they are incurred and earned respectively, and production oriented expenses are charged to specific jobs by a job order system. Indirect costs are allocated on a direct labor hour basis. Also, NIF utilizes a full absorption costing method to value completed production in accordance with Generally Accepted Accounting Principles. (NAVCOMPT-B, 1985)

Bryant (1988) and Murphy (1988) investigated the adequacy of the NIF cost accounting system to enable its use in a RAMP manufacturing facility and determined changes needed to more accurately account for RAMP resources. These changes focused on indirect cost definitions and indirect cost allocation methods. Others, such as Cooper and Kaplan (1988b), have criticized traditional cost accounting systems that use single, predetermined overhead rates for their inability to properly account for product diversity. Shank (1988) wrote about the perils of cost allocation based on production volumes.

Euske (In press) describes the development of traditional cost accounting systems and argues that they were designed primarily for external reporting, not for internal management control purposes, such as product costing. The external focus, although important, does not give priority to the tracking of costs to specific units of output; therefore, the external fiduciary reporting emphasis has been able to appropriately ignore many internal changes (Euske, In press). For instance,

> An increasing amount of costs have slipped from the direct cost category into other categories. Period costs have increased. Cost pools have become less homogeneous. Size, complexity, and a rapidly changing environment have made it difficult to understand how costs are related to outputs.
> (Euske, In press)

Indeed, the relating of costs to output is especially difficult within a RAMP manufacturing facility. To illustrate this point, difficulty arises because RAMP requires an extensive investment in automation (machinery); and, NIF activities typically assign machinery costs to an overhead account. This machinery overhead is then traced to products via a burdened labor rate and, as is demonstrated below, direct labor is rapidly becoming an insignificant factor of total manufacturing costs.

Therefore, the increasing costs of machinery are related to products through the relatively decreasing labor base. This could lead to errors in the cost tracking process. (NAVCOMPT-B, 1985; Raffish, 1991)

The combination of a decline in the significance of labor costs and the use of burdened labor rates to allocate overhead gives rise to various cost accounting issues.

C. TRADITIONAL ACCOUNTING SYSTEMS DESIGN

This section addresses the issue of why traditional cost accounting systems have become less effective in accurately accounting for the use of resources in todays automated manufacturing environment. An argument is made that distorted cost information is the result of accounting choices made decades ago when most manufacturing concerns focused on a narrow range of products and the principal production costs of these products were direct labor and direct materials which could easily be traced to a final product. (Cooper and Kaplan, 1988b)

1. Traditional Cost Accounting: Why Less Effective?

> It's not that traditional cost accounting doesn't work – it's that the world it was designed for is rapidly disappearing. (Raffish, 1991, p. 36)

Composition of the percentage of production costs have shifted from direct labor costs to direct materials and a significantly increased overhead category. (Euske, In press; Murphy, 1988) For example, Figure 3.1 depicts a 20 year trend of production costs which are segregated into the three main components: labor, material and overhead. Note, in 1980, direct labor comprised only 15 percent of the total production cost; today, some have estimated that labor costs will be only five percent of total production costs by the end of the decade. (Raffish, 1991) To

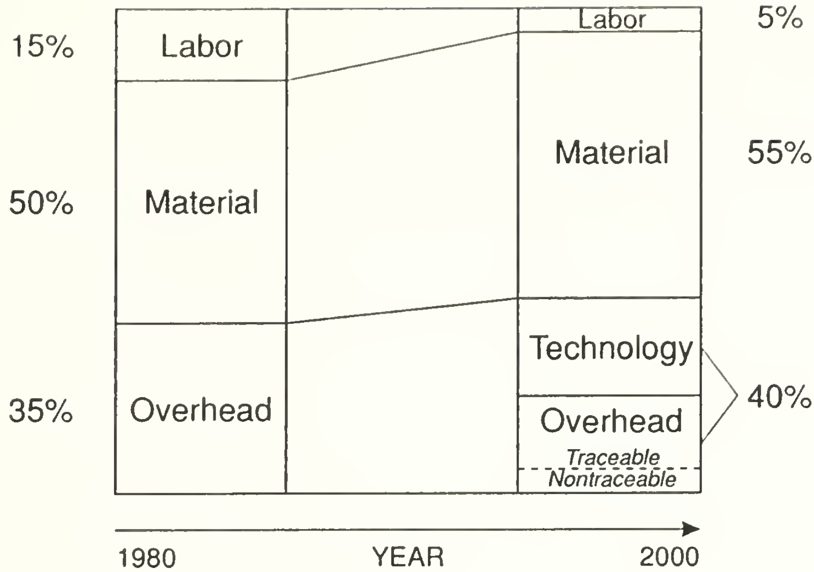

Figure 3.1: Labor Cost vs. Total Product Cost

Source: Raffish, 1991

illustrate this point, years ago a laborer might have taken 11 hours to insert circuit chips, diodes, transistors, and capacitors by hand; however, today this process might be accomplished with machinery in just seven minutes. The problem is that the machinery may have cost millions of dollars and now this cost has become part of the "increased" overhead or indirect account which is traced to products via a labor hour burden rate. Yet, many manufacturing concerns, including NIF activities, continue to trace these rising overhead and support costs by a diminishing direct labor base. Consequently, in some cases labor hour burden rates approach 1,000 percent. (Cooper and Kaplan, 1988a; NAVCOMPT-A, Undated)

Typically, traditional costing systems use a two stage costing process that first traces costs to a cost center and then to individual products. Many different cost tracing can be used in the first stage to assign costs from overhead accounts to an appropriate cost center, but labor hours are used primarily in the second

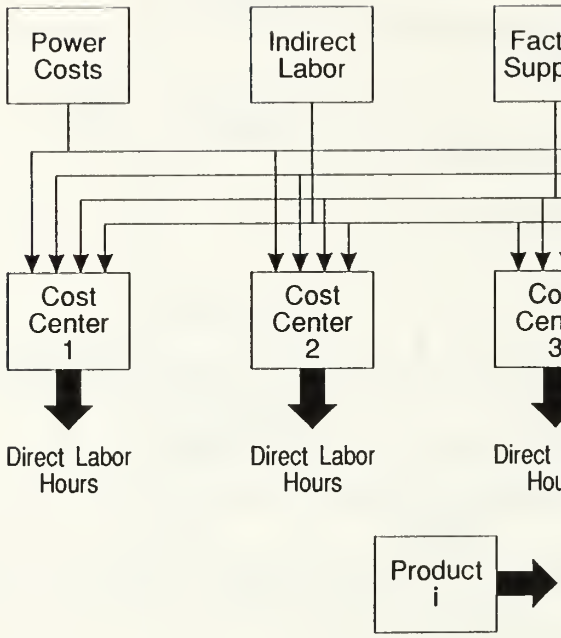

Figure 3.2: Cost Accounting System Allocation Process

Source: Cooper and Kaplan, 1988a

stage to trace overhead from the cost center to the final product. (Cooper and Kaplan, 1988a) Figure 3.2 depicts the methodology of a typical cost accounting system process.

Second stage procedures of tracing overhead to the final product based on labor hours may have been adequate years ago when direct labor was still the principal manufacturing cost. However, today some manufacturers have recognized the declining role of labor and have introduced other bases to assign cost such as machine hours or material costs. Although the use of multiple bases allows for better attribution of costs to the products, it assumes that all allocated costs behave in the same manner and increase in direct relationship to production volume (Cooper and Kaplan, 1988a). This assumption may be inaccurate since there are many supporting costs that vary with the diversity and complexity of products and not

merely by the number of units produced. (Cooper and Kaplan, 1988a) For the RAMP PWA Manufacturing System, examples of these supporting costs include general and administrative (e.g., personnel department, payroll, comptroller, fire and police protection), engineering costs, and logistics cost (e.g., materials acquisition or differing shipping requirements).

In order to achieve accurate product cost, the costing process used must be capable of accounting for all major aspects of product diversity. The bases for assigning costs should be chosen such that they take into account how indirect production costs vary in the long run with regard to both production volume and to the activities necessary to produce disparate items (PWAs) in the same facility. For this reason, many manufacturers today are exploring alternatives to traditional cost accounting systems. (Cooper and Kaplan, 1988a)

Some have argued the prohibitively high expense of collecting and processing data have made it difficult to justify more sophisticated methods (other than a direct labor hour basis). (Cooper and Kaplan, 1988a; Euske, In press) However, simplistic approaches to tracing factory overhead are not longer justified – especially given the improved capabilities of management information systems such as the RAMP Cost and Performance Measurement subsystem (RCPMS).

The inadequacies of traditional cost accounting systems have recently been the focus of much research. These efforts have identified many failings – in particular, the inability of traditional cost accounting systems to report product costs to a reasonable level of accuracy. Cooper and Kaplan (1988b) have proposed that the distortion in reported product costs could be reduced, if not eliminated, by the use of an activity-based costing (ABC) system.

D. ACTIVITY-BASED COSTING

This section explains the terminology and mechanics of ABC and how it can provide a more reasonable estimate of product costs.

1. Activity-Based Costing: Process of Activity Analysis

An appropriate beginning for discussing activity analysis is to understand the importance of "thinking in terms of activities."

> Three basic concepts are important in thinking about designing systems that focus on costing the appropriate tasks or activities: activity, driver, and process. An activity is a task performed in the organization that can be assigned costs (e.g., labor hours x cost per hour = cost of task). Examples of tasks are designing, order entry, or machining of parts.
> The second concept that is important is that of the "driver", a generator of cost or activity. A driver can be thought of as an event or decision. Drivers are not activities. Examples of drivers are customer commitments, decisions on employee training, material shortages, or missed schedules. Activities are associated with each driver, and therefore, costs are associated with each driver.
> The third concept of importance is "process". A process is a chain of drivers (e.g., incomplete design => engineering changes => material shortages => missed schedules). The drivers are associated with activities, then costs. The result is the cost impact of decisions and events within the process. (Euske, In press)

The three basic concepts, activity, driver, and process provide the framework in which activity analysis is conducted. Activity analysis is a method of identifying what an organization does. The analysis helps develop an understanding of all the manufacturing activities and how they fit into the overall business strategy. Moreover, activity analysis is concerned with what is done and what resources are consumed while carrying on the manufacturing process. Activity analysis is used to identify significant activities and analyzes the input and output of each. (CAM-I, CMS, 1990) Figure 3.3 depicts the structure of activity analysis.

Referring to Figure 3.3, the mechanics of activity analysis are illustrated when a manufacturer acquires inputs (e.g., integrated circuit chips, circuit boards,

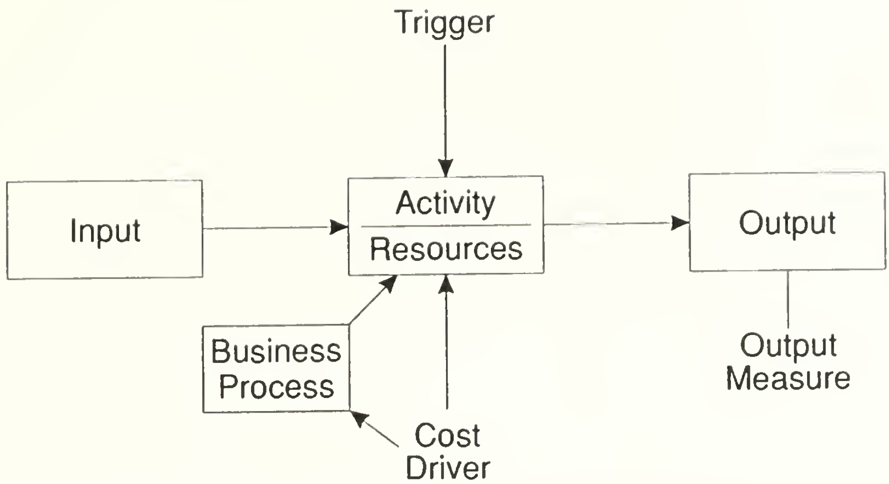

Figure 3.3: Structure of Activity Analysis

Source: CAM-I, CMS, 1990

diodes, capacitors) to satisfy a customer order for a PWA. Although many activities are required in the manufacture of a PWA, an activity, such as insert an integrated circuit chip, can be isolated. This activity serves as a trigger to use the resources of the manufacturer (i.e., labor, material, technology) during the business process. The result of the business process, through a series of activities, is an output - a PWA. The output measure, therefore, is simply a description of how many times the activity was accomplished. And cost drivers are events or decisions that cause activities (e.g., a defective PWA requires rework). (CAM-I, CMS, 1990; Euske, In press)

2. Activity-Based Costing: Defined and Described

> The concept behind ABC is that the cost of a product is equal to the cost of the raw materials used plus the sum of the costs of all activities required to manufacture and deliver the product (Beaujon, 1990, p. 51).

Since an organization's activities exist only to support the production and delivery of a product, all costs ought to be considered product costs which should be traced to an individual product through its manufacturing activities. Activities

consume resources such as labor, materials, or machine time to produce an output (product). (Cooper, 1988; Raffish, 1991)

ABC systems maintain and process data on activities and products. These systems trace costs to products according to the activities performed to produce them (Turner, 1990). Precision in the tracking of costs, first from resources to activities, and then from activities to specific products, stems from the use of multiple bases for assigning costs. This technique allows an ABC system to treat more costs as variable which can then be directly attributed to a product. And direct attribution of costs to products gives rise to a more accurate product price. (Cooper, 1989)

Activities, and therefore, their costs, are caused by cost drivers which are those events or decisions that cause costs to arise or result in increased costs but do not necessarily add value (Euske, In press; Stasey, 1985). Moreover, cost drivers could be thought of as agents that cause activities to happen or a factor that has a direct influence on the cost and performance of subsequent activities and processes. Cost drivers affect the cost of activities and activities consume resources. (Euske, In press; Raffish, 1991; CAM-I CMS, 1990) Examples of cost drivers are:

- an engineering change order.
- a returned, defective circuit board.
- faulty design.
- a special order.
- a rush order.
- urgent shipping requirement.

- materials ordering.

- personnel hiring.

Traditional standard cost systems are designed not to measure product costs per se, but to value inventory (Euske, In press). The standard costs often bear no relation to the resources consumed to design, produce, and deliver the product (Kaplan, 1988). Herein lies the fundamental difference between traditional costing systems and ABC systems - traditional costing systems focus on the product as the consumer of an organization's resources whereas ABC systems focus on the activities of a manufacturer as the consumer of resources. In ABC systems, activities consume resources and products consume activities. (Beaujon, 1990)

Product costs reported by an ABC system can differ from the corresponding costs reported by a traditional costing system. These differences arise because of the ABC system's more flexible approach to tracking costs. An ABC system is nothing more than a refined extension of the two-stage costing process previously discussed. The refinement evolves from the attempt to more accurately track the costs of the many activities involved in the manufacture of a product that are indirectly related to production volume. Not only does the nature of the tracking used in an ABC system differ from a traditional system, but also a large number of cost relationships may be employed. Traditional costing systems can use multiple second stage allocation bases (e.g., direct labor hours, machine hours, materials costs). ABC systems, however, may use a myriad of allocation bases predicated upon defined activities and their associated cost drivers. These additional relationships allow an ABC system to better capture the economic nonproportionalities inherent in production and, hence, more accurately report product costs. (Cooper and Kaplan, 1988b; Cooper, 1989)

The objective of activity costing, therefore, is to relate the cost of an overhead or indirect activity as directly as possible with the product that demands that activity. (Cooper and Kaplan, 1988b; Troxel and Weber, 1990)

The required number of relationships depends upon the desired level of accuracy in reported product costs and on the complexity of the product mix being produced. However, Cooper (1988) emphasizes product mix complexity as being the dominant factor in determining the adequate number of relationships. Two of his three factors are germane to the RAMP PWA project: product diversity and volume diversity. The greater the desired level of accuracy, the larger the number of cost relationships. Of course, there shall be some point in which the benefit derived from greater accuracy is outweighed by the costs. (Cooper, 1989)

Once a decision has been made regarding the appropriate number of cost relationships, the cost driver selection process, which is discussed below, can be considered.

3. How is an Appropriate Cost Driver Selected?

Cooper lists three important factors which should be considered during the cost driver selection process:

> The ease of obtaining the data required by that cost driver (cost of measurement).
>
> The correlation of the consumption of the activity implied by the cost driver (degree of correlation).
>
> The behavior induced by that driver (behavioral effects).
>
> (Cooper, 1989, p. 42)

Cost drivers must be measurable; however, the costs associated with measuring should not exceed the benefit derived. Therefore, ABC systems should use

drivers whose measures are both easily obtained and are a true driver of the process costs. (CAM-I, CMS, 1990)

A distinction can be made between drivers that indirectly relate to the consumption of activities by products and drivers that directly relate to the consumption of activities by products. For example, an indirect measure would be the "number of inspections" as compared with a direct measure "duration of the inspection". Typically, drivers which have an indirect relationship are less expensive. (Cooper, 1989)

Which driver to select depends upon the desired level of accuracy and the complexity of the product mix. If, for example, the Naval Avionics Center's goal for RAMP was a very high degree of accuracy in product costing and a given circuit board was part of a relatively homogeneous production run, then either the indirect driver "number of inspections, or the direct driver, "duration of the inspection" would suffice because there is little or no diversity between boards. On the other hand, if the center's goal remained a very high degree of accuracy but the circuit board was part of a relatively heterogeneous production run (as most are), then the direct driver, "duration of the inspection" would be more appropriate. (Cooper, 1989) Throughput measures are among the capabilities of the RAMP Manufacturing System. With RAMP's bar coding and scanning equipment (which are installed at all workstations), the tracking of throughput times and their associated costs can easily be directly tracked to an individual circuit board. (RTIF Program Document-D, 1989)

Use of indirect drivers to measure the consumption of activities by products runs the risk that the cost driver will introduce distortions into reported product costs since they do not accurately measure the actual consumption of the activities. If, for example, an inspection requires varying amounts of time (diversity), use

of the indirect driver, "number of inspections", will not closely correlate with the use of the direct driver, "duration of the inspection." If number of inspections is the cost driver used, a circuit board that requires a longer inspection time will be undercosted, while a circuit board that requires a shorter inspection time will be overcosted. (Cooper, 1989)

The selection of a cost driver influences an individual's behavior. "In general, a cost driver affects behavior if individuals feel that their performance will in some way be evaluated based on the cost per unit of that cost driver or the quantity of that driver consumed." (Cooper, 1989, p. 44) The behavioral effects can either reinforce or oppose a manufacturer's objective such as reducing costs. For example, if one of RAMP's objectives were to quickly manufacture and deliver completed wiring assemblies to fleet units and reducing the number of shipments had been selected as the driver, laborers working the shipping department may be inclined to await the end of the workday before shipping an urgently needed assembly in hopes that a second or third assembly bound for the same destination would appear. The conflict comes about because the laborer's working the shipping department are evaluated on the basis of reducing costs (i.e, lowering the number of individual shipments). Consequently, the original objective to quickly manufacture and deliver an assembly has been negatively influenced by the selection of the driver, number of shipments.

E. ACTIVITY-BASED COSTING: AN OVERVIEW OF HOW IT WORKS

This section addresses the design of an ABC system. The purpose is to bring together the terminology and processes presented earlier and to discuss the mechanics of costs flow within an ABC system.

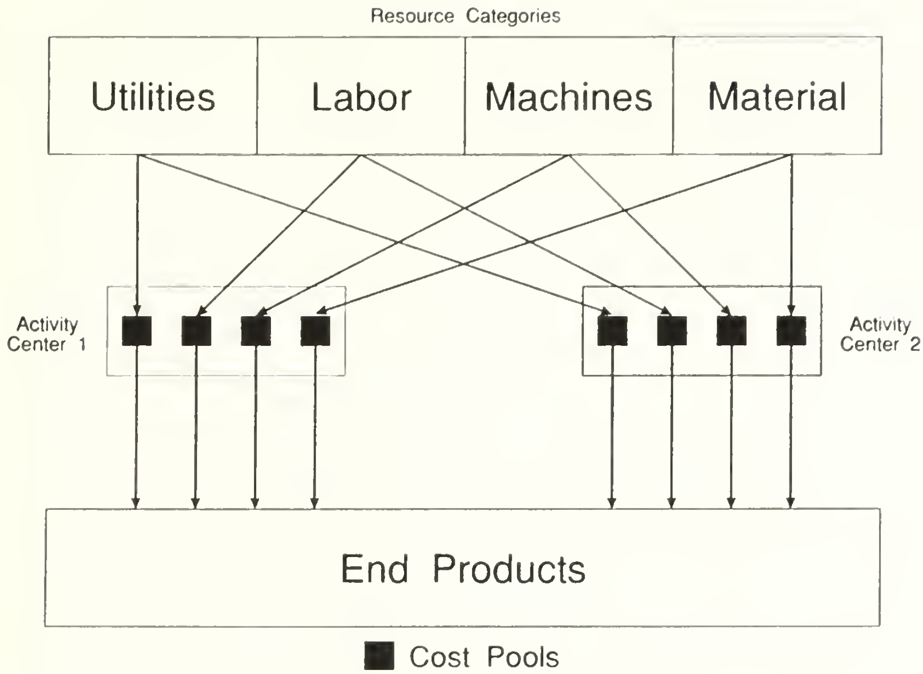

Figure 3.4: Two-Stage Activity Costing Process

Source: Beaujon, 1990

1. ABC Design

Recall that in stage-one of the two-stage costing process costs were traced to a cost center. In stage-two the costs are traced to the final product. In an ABC system's stage-one costing procedure, the issue is how to trace resources such as labor, materials, and technology to activities. The stage-two costing issue is how to trace the costs of resources, through activities, to products. Figure 3.4 depicts a two-stage activity costing process.

In an ABC system, cost pools are generated by using stage-one cost drivers to distribute resources among a set of activity centers. These resources are then assigned to individual products using stage-two cost drivers. (Beaujon, 1990)

Here, activity centers serve as an intermediary in the tracing of costs to products. Once the cost pools are established and appropriate cost drivers assigned, costs flow from resources, to activity cost pools, then to the product. (Beaujon, 1990) For the RAMP PWA facility, the activity centers could be the 13 workstations which comprise the manufacturing cell. Each workstation (i.e., activity center) has a physical meaning. Additionally, the resources consumed by each workstation are expected to be significant.

In cases where costs cannot be directly traced to products, ABC systems will either: 1) Assign indirect costs traceable to a distinct activity to that cost pool, 2) Assign indirect costs which are not traceable to a specific activity to each cost pool by employing an allocation basis appropriate to the cost, or 3) Collect indirect costs lacking an appropriate allocation basis (general and administrative) in a residual pool and allocate directly to the product using "units" or "value" produced as the cost driver. This is also done in traditional costing systems. The ABC system, however, 1) should have fewer costs that are not directly traced and 2) may have more bases used to allocate the costs. ABC systems were designed to overcome the cost distortion problems associated with traditional costing systems. The results of the ABC approach is more accurate product cost information.

The next chapter presents a hypothetical RAMP PWA product pricing model using both a traditional costing approach and an ABC approach to highlight product price differentiation.

IV. PRODUCT COSTING DIFFERENCES: A HYPOTHETICAL MODEL

This chapter provides a hypothetical illustration of operations for the RAMP PWA center which demonstrates the differences in cost information obtained from a traditional costing system and an ABC system. The illustration is not intended to be comprehensive. However, it is intended to capture the essence of an ABC system. As will also be seen, use of an ABC system does not change the total cost incurred by a manufacturer, rather it generates a more precise estimate of the product cost.

A. TRADITIONAL VS. ACTIVITY PRODUCT COSTING

Some assumptions must be made in order to simplify the following example so that the concepts behind ABC are not lost in complexity. The illustration was designed to focus on how both product and volume diversity can cause cost distortions in a hypothetical RAMP PWA center. The assumptions are:

- The RAMP PWA center is in operation.
- Only internal RAMP PWA product costing issues are considered (i.e., issues of allocating the NAC general administrative and production overhead expenses to RAMP PWA are not considered).
- The 13 workstations of the RAMP PWA Manufacturing System are considered as a single production department – "machines".
- The production department manufactures printed circuit boards and employs one manager, six supervisors, and numerous laborers. Each supervisor is responsible for several machines. Each machine requires more than one laborer.

- Differing types of raw materials required in the manufacture of printed circuit boards are represented by the disparity in the number of components per board.
- The machine department is operating at full capacity.
- Shipping costs are assumed to be equal for all boards. Differences in destination charges or types of packing material/methods are not considered.

Information in Table 4.1 is used to compare the two costing methods. The table depicts basic production and standard cost statistics envisioned for a typical day in the RAMP PWA center. Production includes the manufacture of three printed wiring assemblies (boards A, B, and C). Note that product diversity exists among the boards: board "A" requires 47 components, board "B" requires 89 components, and board "C" requires only 28 components. Additionally, product diversity is exacerbated by using differing machine throughput times for each board type. Production volume diversity is represented by the varying production run requirements as well as the number of boards produced during each run. For example, there are: 1) Ten units of board "A" produced in five production runs, 2) Five units of board "B" produced in three production runs, and 3) Seven units of board "C" produced in two production runs.

First, product costing will be developed under a traditional system and then under an ABC system. Second, a comparison of each costing system's product costs are evaluated.

The procedure for calculating the costs of the three printed circuit boards using a traditional approach is described below:

- Charge each product for raw materials cost (the sum of purchased components x price).

- charge each product for direct labor cost (labor hours per board x labor hour rate).

- Assign overhead costs to boards using a two-stage costing process. In stage one, assign costs of overhead and support departments to the production department (machines) based on some relevant measure of activity (e.g., square feet of floor space for janitorial costs, machine value for insurance costs, employee head count for personnel costs). In stage two, assign costs to circuit boards based on some measure of throughput or output volume in the production department (i.e., labor hours).

In this example, there is only one production department (machines), to which 100 percent of the overhead is assigned in the first stage. Although the existence of this single production department assures an accurate first stage assignment of costs, it does not automatically result in an accurate assignment to individual products within that department.

If, however, multiple production departments exist, any of several methods for assigning overhead in stage one may be used. For example, support costs of the purchasing department may not be a function of labor or units of output, but could be a function of the number of parts used. Therefore, the number of parts used would be an appropriate cost driver to assign the costs of purchasing to the production department. This holds true across the spectrum of support costs with other examples being square feet of floor space for janitorial costs or machine value for insurance costs.

With set-up labor included, the overhead to be assigned to the production department is shown in Table 4.2.

TABLE 4.1: RAMP PWA CENTER PRODUCTION AND COST STATISTICS

	BOARD "A"	BOARD "B"	BOARD "C"
PRODUCTION	10 units in 5 runs	5 units in 3 runs	7 units in 2 runs
SHIPMENTS	10 units in 3 shipments	5 units in 2 shipments	7 units in 1 shipment
PRODUCTION COSTS:			
Raw Material (number of components)	47 @ $12.00 ea	89 @ $8.00 ea	28 @ $21.00 ea
Materials cost/unit	$564.00	$712.00	$588.00
Set-up labor – (total – 19 hrs @ $15.00/hr)	2 hrs per production run	1 hr per production run	3 hrs per production run
– number hrs/run	10	3	6
(Direct) Run Labor – (total - 152.45 hrs @ $15.00/hr)	0.15 hr per unit	0.03 hr per unit	0.35 hr per unit
– number hrs/run	70.50	13.35	68.60
– number hrs/unit	7.05	2.67	9.8
Machine Use – (total – 121.8 hrs @ $100.00/hr)	0.10 hr per unit	0.08 hr per unit	0.20 hr per unit
– number hrs/run	47.0	35.60	39.20
– number hrs/unit	4.7	7.12	5.6
Engineering Process Plans Required	2	1	3
OTHER OVERHEAD			
–Receiving Department	$1153.85/day		
–Engineering/Design Department	$1923.08/day		
–Shipping Department	$ 769.23/day		

(Information presented in Tables 4.1 through 4.3 are based on an example by Shank, 1988)

TABLE 4.2: PRODUCTION DEPARTMENT OVERHEAD

Directly Assignable Overhead	
Machine Costs	$12,180.00
Allocated Overhead	
Set-up Receiving Engineering/Design Shipping	285.00 1,153.85 1,923.08 769.23
Total Overhead	16,311.16

Machine Costs = 121.8 hrs x $100/hr

Set-up = 19 hrs x $15/hr

In this traditional costing system, overhead is assigned to products based on direct labor hours. The RAMP PWA center would calculate the unit costs of circuit boards A, B, and C as depicted in Table 4.3.

Having calculated unit costs under a traditional system, let's examine the potential effects of an ABC system. In addition to the information provided in Table 4.1, five considerations crucial to activity costing are considered which emphasize the focus of activity costing systems on identifying factors that result in product cost differentiation:

1. Break out set-up labor from the overhead pool and assign it to individual boards based on the set-up time per production run, multiplied by the labor rate, multiplied by the number of production runs, and then divide by the total number of boards produced. By defining the activity "production run set-ups" and the cost driver "number of set-ups", costs associated with this activity can now be directly attributed to individual circuit boards. Table 4.4 provides unit cost calculations for set-up costs using an ABC system.

2. Break out the receiving department costs from the overhead pool and assign it to the individual boards based on the number of parts handled per board. Receiving department cost per part is calculated by the total receiving department costs divided by the total number of parts required for all boards (A+B+C). By defining the activity "number of parts handled" and the cost driver "number of parts required per board", costs associated with this activity can now be directly attributed to individual circuit boards. Table 4.5 provides unit cost calculations for the Receiving Department costs using an ABC system.

TABLE 4.3: CIRCUIT BOARD UNIT COSTS

Applied Overhead was calculated as follows:		
		Overhead Rate
Machines	$12,180.00	
Set-up	285.00	(total ovhd/labor $'s) =
Receiving	1,153.85	($16,311.16/$2,286.75)* =
Eng/Design	1,923.08	7.1329 or 713.29%
Shipping	769.23	
		(*152.45 hrs x $15.00/hr)
Total	$16,311.16	

Unit Overhead was Calculated as Follows:

	Board "A"	Board "B"	Board "C"
Direct Labor $'s	$105.75	$ 40.05	$147.00
Overhead Rate(%)	x 713.29	x 713.29	x 713.29
Applied Overhead	$754.30	$285.67	$1,048.54

Unit Cost Calculations Using Traditional Costing

	Board "A"	Board "B"	Board "C"
Raw Material	$ 584.00	$ 712.00	$ 588.00
Direct Labor	105.75	40.05	147.00
Overhead (labor $ basis)	754.30	285.67	1,048.54
Total Unit Costs	$1,424.05	$1,037.72	$1,783.54

TABLE 4.4: UNIT COST CALCULATIONS FOR SET-UP COSTS (ABC SYSTEM)

	Board "A"	Board "B"	Board "C"
Number of Runs	5	3	2
Set-up Labor/Run	x 2 hrs	x 1 hr	x 3 hrs
Set-up Labor Hours	10	3	6
Labor Rate	x $15.00 hr	x $15.00 hr	x $15.00 hr
Set-up Costs	$150.00	$45.00	$90.00
Number of Units (divide)	10	5	7
Set-up Cost Per Board	$15.00	$ 9.00	$12.86

TABLE 4.5: UNIT COST CALCULATIONS FOR RECEIVING DEPARTMENT COSTS (ABC SYSTEM)

	Board "A"	Board "B"	Board "C"
Number of Parts/bd	47	89	28
Number of Boards	x 10	x 5	x 7
Number of Parts/bd	470	445	196

Receiving Dept Unit Costs Were Calculated as Follows:

Total Number of Parts Handled (470 + 445 + 196 = 1,111)

Receiving Overhead Costs/Total Number Parts Handled = Rate
$1,153.85/1,111 = $1.0386 per part handled

Receiving Dept Unit Cost Per Board Assigned as Follows:

	Board "A"	Board "B"	Board "C"
Number of Parts/bd	47	89	28
Rate Per Part	x 1.0386	x 1.0386	x 1.0386
Receiving Dept Costs Per Board	$48.81	$92.44	$29.08
	======	======	======

3. Break out Engineering Design costs from the overhead pool and assign it to individual boards based on the number of process plans required to design and test each type of board. Engineering Design costs per board is calculated by dividing the total cost for Engineering Design by the number of process plans generated which gives a per plan rate. This rate, multiplied by the number of plans required for each board type, and divided by the number of boards per type results in a unit cost. By defining the activity "process plans" and the cost driver "number of process plans generated", costs associated with this activity can now be directly attributed to individual circuit boards. Table 4.6 provides unit cost calculations for the Engineering Design Department costs using an ABC system.

4. Break out the Shipping Department costs from the overhead pool and assign it to individual boards based on the number of shipments required. Individual shipping costs are calculated by dividing the total cost of the Shipping Department by the number of shipments required, which gives a per shipment rate. This rate, multiplied by the number of shipments, and divided by the number of boards per type results in a unit cost. By defining the activity "shipments required" and the cost driver "number of shipments", costs associated with this activity can now be directly attributed to individual shipments of circuit boards. Table 4.7 provides unit cost calculations for the Shipping Department costs using an ABC system.

5. Break out the machinery costs from the overhead pool and assign it to individual boards based on the amount of time spent in the production

TABLE 4.6: UNIT COST CALCULATIONS FOR ENGINEERING DESIGN DEPARTMENT COSTS (ABC SYSTEM)

Process Plan Unit Costs Were Calculated as Follows:

Total Number of Plans Generated (A + B + C)(2 + 1 + 3 = 6)

Engineering Design Costs/Number of Process Plans = Rate
$1,923.08/6 = $320.5133 Cost Per Plan Generated

Engineering Design Department Unit Cost Per Board Assigned As Follows:

	Board "A"	Board "B"	Board "C"
Number Process Plans	2	1	3
Cost Per Plan	x $320.5133	x $320.5133	x $320.5133
Cost Per Board Type	$641.03	$320.51	$961.54
Number of Boards Per Type (divide)	10	5	7
Eng Design Dept Costs Per Board	$64.10	$64.10	$137.36
	======	======	======

TABLE 4.7: UNIT COST CALCULATIONS FOR SHIPPING DEPARTMENT COSTS (ABC SYSTEM)

Shipping Unit Costs Were Calculated As Follows:

Total Number of Shipments (A + B + C) (3 + 2 + 1 = 6)
Shipping Costs/Number of Shipments = Rate
769.23/6 = $128.205 Cost Per Shipment

Unit Costs Per Shipment Assigned As Follows:

	Board "A"	Board "B"	Board "C"
Number Shipments	3	2	1
Cost Per Shipment	x $128.205	x $128.205	x $128.205
Cost Per Board Type	$384.62	$256.41	$128.21
Number of Boards Per Type (divide)	10	5	7
Shipping Dept Costs Per Board	$38.46	$51.28	$18.32

TABLE 4.8: UNIT COST CALCULATIONS FOR MACHINE DEPARTMENT COSTS (ABC SYSTEM)

	Board "A"	Board "B"	Board "C"
Hours Per Board Type	47	35.6	39.2
Machine Rate	x $100.00	x $100.00	x $100.00
Cost Per Board Type	$4,700.00	$3,560.00	$3,920.00
Number of Boards Per Type (divide)	10	5	7
Machine Dept Costs Per Board	$470.00	$712.00	$560.00

unit "machines". Individual machinery costs are calculated by multiplying the hourly rate for machines by the amount of time spent in the machinery process. Dividing by the number of each type of board results in a unit cost. By defining the activity "machinery process" and the cost driver "time spent in the machinery process", costs associated with this activity can be directly attributed to individual circuit boards. Table 4.8 provides machine time cost calculations for the Machine Department costs using an ABC system.

Using the ABC method of directly attributing costs to individual products, rather than aggregating these indirect costs into an overhead pool and then assigning them to products based on some volume related measure results in differences in cost information obtained. Table 4.9 depicts unit

cost information calculated by using the two cost accounting methods. The activity-based cost system presents a more detailed estimate of product costs. Note the differences in unit costs when comparing the two costing systems. When the ABC system is used, Board "A" shows a decrease of 9.03 percent, Board "B" shows an increase of 38.3 percent, and, Board "C" shows a 19.5 percent decrease in unit cost.

Activity costing does not change the total cost incurred by a manufacturer. It merely presents a more detailed or accurate cost estimate. Table 4.10 depicts total manufacturing costs derived using both systems.

In summary, this chapter discussed the reasons why traditional cost accounting systems may present a distorted estimate of product costs. Causes for these distortions can be traced to product diversity such as differing quantities of raw materials required in the manufacturing process and volume diversity such as the numbers of circuit boards produced during a production run. When traditional cost accounting systems were designed, these causes were typically not important and were not captured in the systems. (Euske, In press)

ABC systems were designed to capture these elements and provide management with more accurate product costs, primarily through direct attribution of costs. The capability for a greater degree of accuracy of an ABC system, is to a large extent, a function of improved capabilities in management information systems (MIS). Today's MIS systems can gather, track, and correlate cost accounting data with relative ease, whereas in the past maintaining such data could have been cost prohibitive. ABC systems should be

TABLE 4.9: COST ACCOUNTING TOTALS

Activity-Based Costing Approach

	Board "A"	Board "B"	Board "C"
Raw Material	$564.00	$712.00	$588.00
Direct Labor	105.75	40.05	147.00
Overhead (labor $ basis)	754.30	285.67	1,048.54
Total Unit Costs	$1,424.05	$1,037.72	$1,783.54
Percent Change in Unit Costs	- 9.03%	+38.3%	-19.5%

Traditional Approach

	Board "A"	Board "B"	Board "C"
Raw Material	$564.00	$712.00	$588.00
Direct Labor	105.75	40.05	147.00
Receiving Dept	48.81	92.44	29.08
Engineering Dept	64.10	64.10	137.36
Shipping Dept	38.46	51.28	18.32
Machinery Dept	470.00	712.00	580.00
Set-up Labor	15.00	9.00	12.86
Total Unit Costs	$1,306.12	$1,680.87	$1,492.62

TABLE 4.10: TOTAL MANUFACTURING COSTS (BOTH SYSTEMS)

Traditional Approach

Board	Unit Cost	x	Quantity	=	Total Costs
A	$1,424.05	x	10	=	$14,240.50
B	1,037.72	x	5	=	5,188.60
C	1,783.54	x	7	=	12,484.78
		Total			$31,913.88*
					=======

Activity-Based Approach

Board	Unit Cost	x	Quantity	=	Total Costs
A	$1,306.12	x	10	=	$13,061.20
B	1,680.86	x	5	=	8,404,35
C	1,492.62	x	7	=	10,448.34
		Total			$31,913.89*
					=======

* Difference is rounding error.

thought of as an update of traditional costing systems in response to a rapidly changing manufacturing environment. As previously stated,

> It's not that traditional cost accounting doesn't work – it's that the world it was designed for is rapidly disappearing. (Raffish, 1991, p. 36)

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The purpose of this thesis was to compare traditional cost accounting with ABC accounting in order to determine not only which costing system would more accurately account for resources within the RAMP PWA center, but also which system produces a more precise estimate of product costs.

Chapter I introduced the thesis objective and described the rapidly changing manufacturing environment as one which is shifting from a labor-intensive environment to a machine-intensive environment. The chapter also highlighted other studies completed by Bryant (1988) and Murphy (1988) which determined the NIF cost accounting system has inadequacies when with a highly automated manufacturing system such as RAMP. Finally, Chapter I explained why a comparison between a traditional costing system and an ABC system was necessary.

Chapter II described the purpose and goals of the RAMP PWA center and presented an overview of the RAMP Manufacturing System. The chapter was intended to provide the reader with an understanding of the automation technologies incorporated in the RAMP PWA center. The chapter also described RAMP PWA as a computer-integrated manufacturing system which could have implications for the design of the cost accounting system.

Chapter III explained how traditional costing systems, such as the one employed by the NAC, could potentially misrepresent product costs, particularly when dealing with product and volume diversity. The chapter also explained how an

ABC system, if properly designed, could provide more accurate cost information as compared with a traditional costing system.

In Chapter IV a hypothetical product pricing model was developed which compared a traditional costing system with an ABC system. Results of this comparison demonstrated that ABC systems may be better able to account for resources within a highly automated manufacturing system such as RAMP.

Based on the studies of Bryant (1988) and Murphy (1988) and the information presented in this thesis, the current configuration of the NIF cost accounting system may not be adequate for either accurately accounting for resources within the RAMP PWA center or for the purpose of accurately costing products.

B. RECOMMENDATIONS

It is recommended that the NAC implement an ABC system in order to more accurately account for resources within the RAMP PWA center and to insure accurate product costing. With the anticipated product and volume diversity incurred in the manufacture of printed wiring assemblies, use of a single, predetermined labor hour allocation base for distributing indirect costs will introduce undesired product cost distortions.

ABC systems were designed to account for both product and volume diversity. ABC systems treat a greater percentage of costs as direct costs of production. This direct attribution of costs to products decreases the total amount of costs that must be treated as indirect. For those costs that are treated as indirect, multiple bases are used to assign the costs.

APPENDIX A
RCPMS Functional Capabilities and Description

The following description of the RCPMS functional capabilities is reprinted from the RAMP Cost/Performance Management System Requirements-Structural Analysis and Dataflow Diagrams Document. (RTIF Program document-E, Undated)

A. BID QUOTATION PROCESSING

RCPMS will provide the capability to generate unit production cost estimates for bid quotation purposes. Estimates will be based on the order and part information supplied to RCPMS by the activity requesting the manufacture of a printed wiring assembly.

The RCPMS production cost estimating process will entail two functions:

- Estimating process costs (including RAMP administrative, engineering, manufacturing, and manufacturing support, and
- Obtaining cost estimates from purchasing for the required bill of materials and external services required for a particular order.

Process costs estimated by RCPMS will be combined with material/external service costs (received by RCPMS from purchasing) and an allocation of NAC's general administrative costs to be distributed to RAMP. The total of these elements will constitute the final product cost estimate. The price quotation is then forwarded to the activity requesting RAMP services with a unique bid identification number. Record closeout entries are made to the request for quotation datastore.

B. ENTER ORDER DATA

Upon acceptance of a request, information containing the funding data and other administrative information necessary to establish accounts for a specific job order are entered.

C. ENTER ORDER SPECIFIC ITEM/FIXTURE REQUISITION

RAMP Production and Inventory Control manages the requisition, use and disposition of order specific fixtures, parts, material and external services through a series of RAMP/ARLSS interface messages called Material Management and Fixture Management.

Material Management tracks the procurement, use, and/or disposition of parts, material, and external services. Fixture Management similarly tracks the requisition and receipt of order specific fixtures.

D. COLLECT AND DISTRIBUTE TRACEABLE LABOR COSTS

Traceable labor cost accounting within RCPMS will consist of four subtasks:

- Obtain standard burdened labor rates from NAC personnel management by functional job category,
- Obtain holiday, day of week, and overtime hourly labor rate differentials,
- Collect labor times by activity and job, and,
- Calculate and distribute resulting activity labor costs to specific jobs.

E. COLLECT AND DISTRIBUTE NON-TRACEABLE COSTS

Expenditures which are not directly assignable to a specific job order number will be applied to production using a two-step allocation procedure.

- Step One - Indirect costs are distributed to the cost pool originating the requirement for expenditure. Cost pools are non-traceable (indirect) cost collection accounts associated with distinct processes or activities.

- Step Two - Costs from these pools are then applied to each job based on the job's demand on the pools' resources. Activity cost drivers are the cost per unit resource associated with each pool. Distribution of indirect costs to cost pools will be accomplished as follows:

  - Indirect costs traceable to a distinct process or activity will be entered in that cost pool.

  - Indirect costs which are not traceable to a specific activity will be distributed to each cost pool employing an allocation basis appropriate to the cost (e.g., heating cost allocated based on cubic area, electricity charges allocated based on power-on time and kilowatt rating of activity equipment).

  - Costs lacking an appropriate allocation basis (general and administrative) will be collected in a residual pool and allocated directly to each job using "units produced" or "value produced" as the cost driver.

The cost pool look-up will contain the cost pool identifier, a list of equipment within each pool, and the process performed by resources contained in that pool. Its purpose is to assist users in determining the appropriate pool destinations for non-traceable costs.

The cost to pool distribution table will maintain cost distribution information for certain recurring indirect costs so that their distribution to costs pools may be accomplished automatically.

Non-traceable labor costs will be collected, distributed to appropriate cost pools, and subsequently allocated to individual job orders.

Non-traceable costs may be incurred by activities or process centers directly (e.g., maintenance performed) or indirectly (fixture produced by activity "a" for use by activity "b"). The distribution of certain recurring costs will be accomplished automatically through postings based on the cost to pool distribution table. Remaining non-traceable costs will be posted to cost pools manually through the use of input screens.

Each cost pool will contain expensed and capitalized sub-accounts. Expensed accounts require charge-off in the current accounting cycle while capitalized accounts are charged over a multi-period horizon dependent on the asset utilization life expectancy.

F. ALLOCATE NON-TRACEABLE ACTIVITY COSTS TO JOBS

This process is concerned with the allocation of non-traceable pooled costs to individual Shop Work Orders (SWO), based on the SWO's demand of resources associated with that pool. This process consists of three subtasks: 1) Maintenance of the activity cost driver data, 2) Allocation of costs to a SWO, based on the cost driver data, and 3) Adjustment of the cost pool to reflect allocations and additions.

Each capital/expense cost pool has an associated cost driver which must be maintained and periodically updated. Three procedures will be used to maintain activity cost drivers: 1) Cost pool balances and remaining useful life will be manually verified through screen query and entry, 2) Cost drivers will

be periodically recalculated, and 3) Recalculated cost drivers will be stored in the Activity Driver Database.

Resource usage for each RAMP activity or operation will be directly recorded from engineering operations data available in the common data base. Operational data may be directly available (e.g., reported run, set-up and move times) or may be in the form of instruments or proxy message (e.g., one SWO implies one board undergoing conformal coating or distributing the costs of the purchasing department on a cost per purchase order basis).

Cost per unit of activity will be combined with activity measurements to produce the indirect cost allocations to each job. Resulting indirect costs are then transferred from the appropriate cost pool to a specific job.

G. JOB CLOSEOUT

Job closeout will occur at order cancellation or job completion. A copy of the order cancellation message will be provided to RCPMS's job closeout function by Production Inventory and Control (PI&C). Similarly, order completion notification will be provided to job closeout by PI&C. A final update of external service charges and cost adjustments for excess material returns will be requested from purchasing and the data base updated accordingly. A final job cost report is then prepared for job closeout.

H. COST REPORT GENERATION AND ARCHIVE

A table of required reports will be maintained containing report titles and due dates. This table will be manually maintained through screen entry and will initiate reports at the appropriate times. In addition, ad-hoc queries and

reports may be generated from existing accounts at any time. Certain end-of-cycle reports will be accompanied by the closing and reopening of accounts for the new accounting cycle. At this time, closed job records will be transferred to the job data archive. (RTIF Program Document-E, Undated)

APPENDIX B
RAMP PWA Workstation Activities

The following description of workstation activities is reprinted from the RAMP PWA Prime-Item Development Specification Document. (RTIF Program Document-D, 1989)

A. RECEIVING WORKSTATION

The Receiving Workstation consists of four individual stations: 1) Dispatch and Manual Storage, 2) Dock, 3) Vertical Carousel, and 4) Kitting. The Vertical Carousel station operator shall request tote tray(s) from vertical carousels, load components into appropriate tote trays, and return tote trays to the vertical carousels. The (printed circuit boards) PWBs for a customer order shall be received at the Dock station and stored in tote trays along with the components. The PWA direct and indirect materials shall be unloaded and transported to the rack storage equipment in the Dispatch and Manual Storage station area.

Once a customer order is issued to the shop floor for production, an operator at the kitting station shall receive the customer order tote tray(s) from the vertical carousel(s) and place them at the kitting station worktable. Next, the operator shall retrieve tote trays from the horizontal carousel AS/RS (Storage and Transportation Workstation). Based on display kitting station terminal graphics and instructions, the operator shall then pick parts from the customer order tote tray and place them in partitioned component tote trays, rotary bin trays,, and PWB tote trays for production. The rotary bin trays, stored in non-partitioned component tote trays are returned to horizontal carousels AS/RS and the empty customer order tote tray(s) is returned to the vertical carousel(s). Barcode readers shall be used

to identify customer order tote trays, component tote trays, rotary bin trays, and PWB tote trays in order to obtain the required kitting instructions. At the Receiving Workstation, one of the six terminals will be the Dock and Vertical Carousel station's workstation controller, which interfaces with the Production and Inventory Control controller. Also, one of the six terminals will be the kitting station's workstation controller, which interfaces with the Manufacturing Cell controller.

B. STORAGE AND TRANSPORTATION WORKSTATION

The Storage and Transportation Workstation shall be a multi-level, horizontal carousel AS/RS. Inserter/Extractor machines equipped with barcode readers shall transfer trays between a workstation conveyor and the AS/RS. Workstation conveyors shall be programmable, power-driven, two-level, bidirectional conveyors. This workstation shall store and retrieve tote trays which contain components, PWBs, and PWBs in pallets for released shop work orders.

The following tote trays shall be handled by the horizontal carousel AS/RS for production of PWAs.

- Component tote trays shall be used to store components for released customer ordered shop work orders. Components are initially placed in these trays at Receiving in a prescribed manner and location. These tote trays shall be automatically stored and retrieved from the AS/RS. A barcode label shall be placed on each tote tray for automatic identification. Upon completion of a workstation operation, these trays shall be returned and stored in the AS/RS.

- Rotary bin trays (Parts Presented Module trays) shall be used to store CDA-assembled components for released customer ordered shop work orders. Components are initially placed in these partitioned trays at the Kitting station in a prescribed manner and location. These tote trays shall be placed inside

of a component tote tray and be automatically stored and retrieved from the AS/RS. A barcode label shall be placed on each tote tray for automatic identification. Upon completion of a workstation operation, these trays shall be returned and stored in the AS/RS.

- PWB tote trays shall be used to store individual PWBs, components which cannot be kitted into component tote trays, and completely assembled PWAs.
- Pallet toe trays shall be used to transport individual PWBs in pallet during the assembly process. A barcode label shall be placed on each pallet for automatic identification purposes.

C. COMPONENT PREPARATION WORKSTATION

The Component Preparation Workstation shall prepare electronic components using manual, semi-automatic, and automatic equipment. These equipment and processes shall tin the components and form the component leads to meet the requirements of DoD-STD-2000.

D. BOARD PREPARATION WORKSTATION

The Board Preparation Workstation shall prepare PWBs, designed in accordance with MIL-P-28809A and MIL-STD-275, to the requirements of DoD-STE-2000. Within this workstation, simple point-to-point masking of PWB pads shall be accomplished and PWBs shall be solder pasted if required after solder mask has been cured in an oven. After the operator is finished preparing the PWB, the operator shall mount an individual PWB onto a pallet, replace the palletized PWB into the tote tray, and then return the tote tray to the AS/RS. The pallet barcode label shall be of metallic base or kapton

type material which shall not be destroyed by heat or chemical solvents in the fluxing, soldering, cleaning or drying processes.

E. PRE-SOLDER ASSEMBLY WORKSTATION

The Pre-Solder Assembly Workstation shall assemble PWAs, designed in accordance with MIL-P-28809A and MIL-STD-275, to the requirements of DoD-STD-2000. This workstation shall be capable of handling a maximum PWB size of 11 x 14 inches in a 12 x 16 inch pallet. The Pre-Solder Assembly Workstation shall consist of CDA station(s) for through-hole devices (THDs), and an automatic placement station for Surface-Mount Devices (SMDs).

F. PRE-SOLDER INSPECTION AND REPAIR WORKSTATION

The Pre-Solder Inspection and Repair Workstation shall be used to inspect 100 percent of the PWAs for defects in the assembly process prior to entering the Solder Workstation. This workstation shall inspect for 1) solder masking defects, 2) solder paste defects, and 3) surface mount device and/or through-hole component placement defects. Identified defects shall be repaired at this workstation. This workstation shall automatically or manually locate, determine pass/fail classification, identify type of assembly defect, and permit an operator to manually repair defective components. The inspection equipment shall automatically or semi-automatically scan each component and clinched lead and determine if it meets the requirements of DoD-STD-2000. The workstation shall consist of two stations: an inspection station and a CAMO repair/rework station for manually repairing defective or missing components and improperly clinched leads.

G. SOLDER WORKSTATION

The Solder Workstation shall solder PWAs designed in accordance with MIL-P-28809 and MIL-STD-275. This workstation shall consist of a Wave Soldering station for through-hole components, Reflow Soldering station for SMD, and a cleaning station for both soldering stations.

- Wave Solder Station: The wave solder machine shall be in-line and computer controlled. Parameters such as belt speed, preheat temperature, solder temperature, and specific gravity of the flux, shall be capable of being automatically controlled, monitored, and recorded.
- Reflow Solder Station: This shall be an in-line operation. The PWAs populated with SMDs and solder paste shall be conveyed through the first heated zone to preheat the components. A second heated zone shall solder the components to the PWB. The reflow solder equipment shall be computer controlled and have the capability for controlling the rate at which the PWA temperature increases.
- Cleaning Station: The PWAs in pallets shall enter the cleaning station directly from wave and/or reflow solder. If the process plan requires additional components to be added after the first pass through wave or reflow solder, the PWAs shall be returned to the pallet tote trays and returned to the AS/RS. The cleaning station shall be an in-line cleaning machine.

H. POST-SOLDER ASSEMBLY WORKSTATION

The Post-Solder Assembly Workstation shall be designed to manually assemble components or parts requiring assembly after solder workstation processing. Manually assembled components are prepared, inserted, and/or soldered at the stations. Work shall be directed from the workstation controller with instructions and supporting graphics.

I. POST-SOLDER INSPECTION AND REPAIR WORKSTATION

The Post-Solder Inspection and Repair Workstation shall automatically or manually locate, determine pass/fail classification, identify type of defective solder joint, and permit an operator to manually repair defective solder joints. The inspection equipment shall automatically scan each solder joint and determine if it meets the requirements of DoD-STD-2000. The workstation shall contain two stations: 1) an inspection station, and 2) a CAMO repair/rework station for manually repairing defective joints.

The three-dimensional, automatic inspection equipment shall be a programmable system which digitizes the PWA image to inspect the PWAs for solder defects. This system shall be capable of being data driven for the downloading of programs and uploading of inspection data to the CAMO repair/rework station and for data storage. The three-dimensional, semi-automatic inspection equipment will be used for back-up and surge capacity. The manual repair station shall have equipment capable of receiving and using the solder defect data downloaded from the inspection equipment.

J. MECHANICAL ASSEMBLY WORKSTATION

The Mechanical Assembly Workstation shall assemble PWAs and is designed to manually separate PWAs from the pallet, and assemble components or parts requiring assembly after Solder Workstation processing. Manually assembled components are prepared, inserted, and/or soldered at these stations. Work shall be directed from the workstation controller with instructions and supporting graphics.

K. TEST WORKSTATION

The Test Workstation shall be required to 1) perform in-circuit tests on required components for proper performance, 2) perform burn-in tests on PWAs for proper performance in the required temperature environments with power applied for a specified time period, and 3) perform troubleshoot and repair on rejected PWAs and return to test for final acceptance.

The PWA Test Workstation shall consist of a workstation controller, a transporter conveyor, and five stations: automatic test, manual test, Automatic Test Program Generation (ATPG), and burn-in, and fixture assembly. The Test workstation is organized around two clusters, consisting of two automatic test stations and one manual workstation which shall meet the calibration requirements of MIL-STD-45662. The ATPG station shall be in two parts, one of which is part of the process planning function, the other part of manufacturing. ATPG shall be the station where the test programs for the automatic test equipment are generated. The PWAs do not go to the ATPG station. The fixture assembly station shall assemble the fixtures required to test PWAs. The PWAs do not go to the fixture assembly station. When

an order arrives, the ATPG software shall be executed on the Product Data Exchange Specification (PDES) file, or on a computer-aided design (CAD) translation of the PDES file, producing a raw test program, exception information, and a fixture file. The PWA schematic, PWA test specifications, if any, and the ATPG output shall be examined by a test engineer. The test engineer estimates the time and facilities required to manually test the PWA and/or develop and debug automatic test programs for the PWA. This information will be used to determine RAMP/PWA test candidacy. If the PWA is accepted as a RAMP test candidate, a test strategy is developed. If manual test, including visual inspection, is part of the strategy, the fixture file shall be released to the fixture assembly station when the PWA is released for production. If additional programming is needed, as for non-library devices, a programmer shall be assigned. As much programming and debugging as can be done before the PWA is built shall be accomplished, minimizing the time required on the RAMP PWA shop floor. After this process planning function is completed and the shop work order is released to manufacturing, all test program modifications will be part of the manufacturing function.

The automatic in-circuit test station shall consist of an automatic combinational tester along with auxiliary equipment, such as barcode readers and terminal, as may be required to implement the purpose and function of the station. The testers in each of the in-circuit test stations need not all be of the same type or identically configured.

L. CONFORMAL COATING WORKSTATION

The Conformal Coating Workstation shall consist of three stations: cleaning, masking, and robotic conformal coating. Cleaning and drying parameters

shall be controlled by the operator as required. After PWAs have been cleaned, the PWAs shall be manually masked. This workstation shall robotically conformal coat PWAs.

M. FINAL QUALITY CONTROL AND PACKAGING WORKSTATION

The Final Quality Control and Packaging Workstation shall receive a conformal coated, assembled PWA from the Production and Storage and Retrieval Workstation, perform a final visual inspection, pack and ship the PWA in accordance with the purchase order requirements, and receive and transmit the data necessary to perform its functions. This workstation shall be equipped with a terminal which will provide access to the data base containing the inspect, package, and ship data, and maintain the necessary records covering the PWA processing. The workstation shall have access to the quality control, packaging, and shipping instructions upon command and display them on the terminal. The first workstation printer shall be capable of printing alpha numeric barcode labels, and the second workstation printer shall be capable of printing alpha numeric shipping documents of up to ten copy pages, e.g., using a daisy wheel type printer. The terminal shall have access to the PWA pedigree file for printout and shipment with the PWA, and/or presentation to a DoD inspector.

Required pedigree information (quality and process data) shall have been recorded for the particular PWAs to form a permanent record. This pedigree information shall be displayed for the Final Quality Inspector. This shall include repairs, process plan, and RAMP PDES deviations in the manufacture

of the PWAs. These are reviewed and inspected. The PWAs shall be checked for compliance with all quality requirements.

N. RAMP PWA QUALITY CONTROL

The actual RAMP PWA quality control operations are incorporated within each functional workstation.

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